RADIOACTIVE TITANIFEROUS HEAVY-MINERAL DEPOSITS IN THE SAN JUAN BASIN, NEW MEXICO AND COLORADO *

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INTRODUCTION

In the course of geologic reconnaissance in the San Juan Basin of New Mexico and Colorado, numerous radioactive, heavy-mineral placers were discovered in Upper Cretaceous sandstones. The majority of the deposits were found during an airborne radiometric survey by the United States Atomic Energy Commission.

The radioactivity may be equivalent to that of a deposit containing 0.09 percent U_3O_8, but chemical analyses show a maximum of only 0.01 percent U_3O_8; hence they cannot be considered a commercial source for uranium. Preliminary assays indicate that many of the deposits average about 16 percent TiO_2 with maximum assays of 32 percent. Titanium occurs mostly in ilmenite and anatase. Zircon and garnet are found in relative abundance in all the deposits and several rare elements are present in significant amounts.

A review of the literature has revealed that similar Upper Cretaceous black sands are found in Montana, in all the major structural basins in Wyoming, and in a single reported occurrence on Grand Mesa in Colorado (Murphy and Houston, 1955).

The paper is limited to a brief description of the physical characteristics, stratigraphic distribution and potential economic significance of the San Juan Basin deposits, in order that new deposits can be recognized.

The author acknowledges the assistance of J. F. Murphy and R. S. Houston of the U. S. Geological Survey, Laramie, Wyoming, for field and laboratory assistance in evaluating the deposits of the San Juan Basin.

OCCURRENCE

Geographic Distribution

Black-sand deposits are known in the northwestern, western, southwestern, southeastern, and eastern parts of the San Juan Basin (fig. 1). In the northwest, 14 separate deposits are known in the southwestern part of

Deposits have also been recognized in the gas wells near Gobernador in the central part of the Basin.

Stratigraphy and Environment

The San Juan Basin contains a classic example of transgressive-regressive sedimentation which has been described by several workers (Sears, Hunt and Hendricks, 1941; Pike, 1947; and Silver, 1951). Complex intertonguing of marine and nonmarine sediments has resulted from the numerous oscillations of the Late Cretaceous sea across the area. The Cretaceous sequence on the northeast side of the Basin is predominantly a marine shale, but on the southwest side the same interval is represented by a sequence of continental sandstone, shale, and coal, with a few interbedded tongues of marine shale (fig. 2). Black-sand deposits are found in the Gallup, Dalton, Point Lookout, and Pictured Cliffs sandstones. These are regressive sandstones which were formed as the sea retreated to the northeast.

Mesa Verde area. A few miles to the south four occurrences have been found along the steeply dipping Hogback monocline. Single deposits are known near both Toadlena and Sanostee, New Mexico, on the west side of the Basin. In the southwestern part a single deposit is known near Standing Rock Trading Post, and another is reported near Gallup, New Mexico. In the southeastern part of the Basin, a few well-exposed deposits occur near Star Lake Trading Post; two deposits have been found on Miguel Creek dome, and another occurs on the B. P. Hovey ranch. Two deposits are also known near Stinking Lake in the eastern part. Two deposits occur near the Herrera ranch southeast of the Basin proper in the Rio Puerco fault belt.

The black sands are beach concentrates and represent a transition from marine to nonmarine beds. All of the known black sands are associated with clean massive well-sorted littoral marine sandstone beds which are overlain by lagoonal coal and shale. To date, no heavy-mineral deposits have been found in the transgressive sandstones of the Basin. These include the so-called "stray sandstone" of the Crevasse Canyon formation, Hosta tongue of the Point Lookout sandstone and the Cliff House sandstone.

Field Characteristics

The deposits are not continuous over broad areas but are narrow lenticular bodies resembling present-day titaniferous beach sands. A persistent northwest trend, parallel to the direction of the Cretaceous strand lines, is found at all the better exposed deposits. This habit could be used as an exploration guide.

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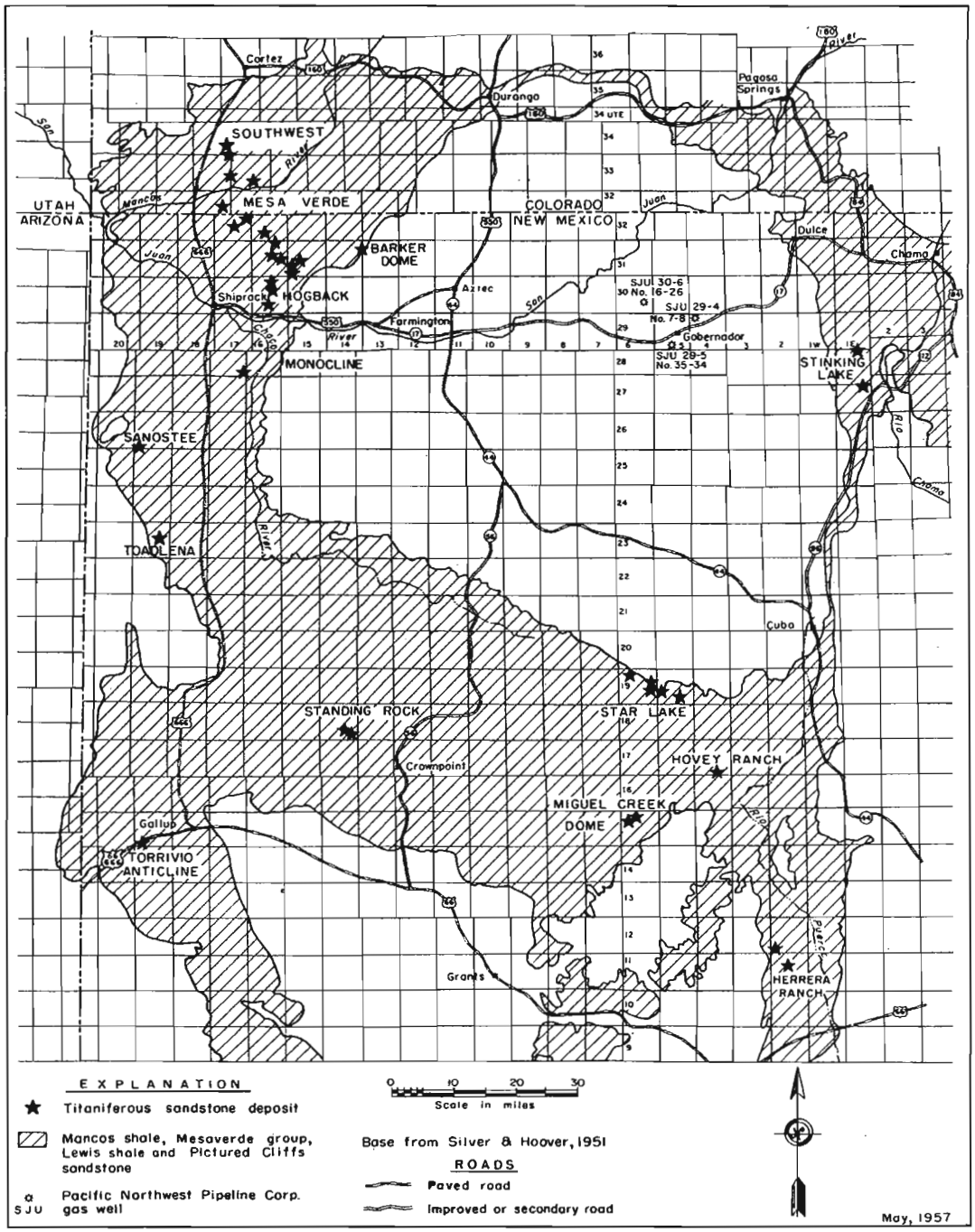

Figure 1. Map showing location of titaniferous sandstone deposits San Juan Basin, New Mexico and Colorado

Deposits range in size from several thousand feet in length and several hundred feet in width to small isolated knobs and ridges a few tens of feet in diameter. They are well cemented with hematite and limonite and are resistant to erosion. The deposits are generally olive gray or or rust brown, but some are brownish black or purplish maroon. They consist of very fine-grained well-sorted blocky sandstones without cross-bedding, in contrast to the surrounding massive cross-bedded medium-to fine-grained sandstones (fig. 3).

Mineralogy

Preliminary work has indicated that the mineralogy of all San Juan Basin deposits is nearly the same, regardless of the formation in which they occur, and all are very similar to the deposits in Wyoming. Detrital heavy minerals make up 50 to 60 percent of the ore. The remainder is

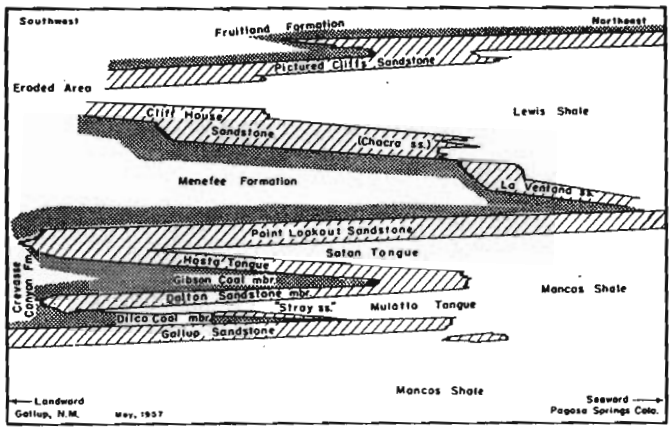

Figure 2. Upper Cretaceous relationships, San Juan Basin

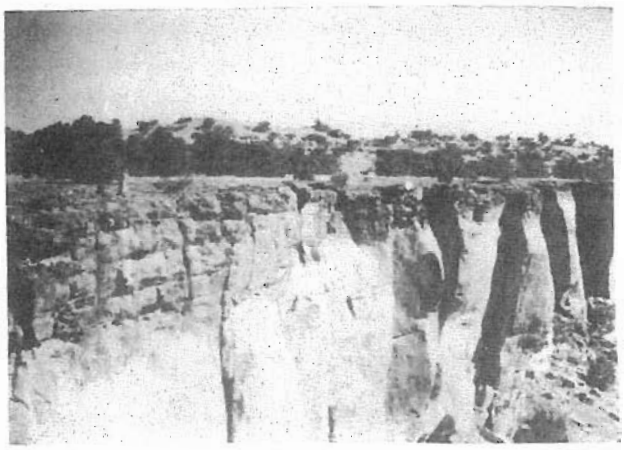

Figure 3. View of the Sanostee deposit in the Gallup sandstone, looking south. Note the gradual thinning to the southwest.

largely quartz. Ilmenite is the most abundant heavy mineral with zircon next in abundance. Other minerals include garnet, monazite, rutil, spinel, epidote, amphibole, magnetite and tourmaline. Unidentified opaque minerals are also present. The heavy fraction averages 15 to 20 percent zircon, 5 to 15 percent garnet, 3 percent other minerals, and the rest ilmenite according to Houston (personal communication, January 11, 1957).

The radioactivity of the titaniferous sandstones, which varies from 5 to 30 times the background reading on the scintillometer, is attributed to the presence of uraniferous zircon and monazite. Some radioactivity has been traced to unidentified opaque minerals believed to contain thorium, which is present in amounts up to 1 percent of the ore.

Three types of zircon are usually present: lavender euhedral, colorless euhedral, and metamict rounded (Houston, personal communication, December 16, 1955). A well-rounded lavender variety is also common in the Point Lookout sandstone deposits. The colorless euhedral variety emits a bright orange fluorescence under short-wave ultraviolet light. This fluorescence is particularly useful in identifying the sands where they are highly weathered and have lost their dark coloration.

Titanium content is generally greatest in those deposits which are most radioactive. Preliminary analyses by Houston (personal communication, January 11, 1957) show that the ilmenite is free of intergrowths with magnetite, and much of it has altered to anatase, some to rutile and rarely to brookite. The alteration has gone so far in some deposits that the original ilmenite grains cannot be recognized. The alteration involves not only conversion to titanium dioxide and ferric oxide but also loss of iron from the original grain; the anatase replaces the original grain and the hematite becomes dispersed in the cement. Certain zones in the deposits do not contain many black minerals, due to the lighter colored alteration products, but actually contain more than 16 percent TiO_2.

Spectrographic analyses (table 1) of bulk samples of a deposit in the Point Lookout sandstone show that the deposit contains roughly one-half to one percent thorium, and such rare earths as cerium, neodymium, and ytterbium, as well as significant amounts of lanthanum, niobium (columbium), and yttrium.

TABLE 1. Typical semiquantitative spectrographic analysis of the heavy-mineral deposits in the Point Lookout sandstone, southwest Mesa Verde area.

ELEMENT	VALUE	ELEMENT	VALUE
Silica	XX.	Copper	.0X-
Aluminum	X.	Lanthanum	.X-
Iron	X.	Niobium	.0X-
Titanium	XX.	Neodymium	.X
Manganese	.X-	Nickel	.0X-
Calcium	.X	Lead	.0X-
Magnesium	.X	Scandium	.0X-
Barium	.0X	Thorium	.X-
Beryllium	.000X-	Vanadium	.X-
Cerium	.X	Yttrium	.X-
Cobalt	.0X-	Ytterbium	.0X-
Chromium	.0X	Zirconium	X.

EXPLANATION

Subgroup	Theoretical Range
XX.	More than 10%
X.	1.0 to 10.0%
.X /	.464 to 1.0%
.X	.215 to .464%
.X-	.10 to .215%

DEPOSITS

Gallup Sandstone

Toadlena — A titaniferous deposit in the Gallup sandstone, about 2 miles south-southeast of the settlement of Toadlena, New Mexico, on the Navajo Indian Reservation, was discovered several years ago but was recognized as a black-sand deposit only recently. An olive-gray zone 1,750 feet long and as much as 6 feet thick is exposed along the strike of the steeply dipping north-trending hogback of Gallup sandstone, which forms the west edge of the San Juan Basin. A grab sample from this deposit assayed 32 percent TiO_2, 0.05 percent U_3O_8 equivalent radiometrically, and 0.01 percent U_3O_8 chemically.

Sanostee — Several miles north of Toadlena a second deposit in the Gallup sandstone, also on the Navajo Indian Reservation, has been discovered recently during Commission reconnaissance near Sanostee, New Mexico. This well-exposed deposit, about 2 miles due north of the school, occurs on a nearly horizontal mesa of Gallup sandstone. The brownish-gray heavy-mineral zone, which averages 12 feet in thickness and 450 feet in width, can be traced continuously N. 30° W. for a little over 1½ miles. Like the Toadlena deposit, the deposit at Sanostee is overlain by a thin carbonaceous shale sequence that may represent the Dilco coal member of the Crevasse Canyon formation. Unlike the majority of the deposits, visible laminations in the heavy minerals are common at both the Sanostee and Toadlena localities.

Torrivio Anticline — A radioactive titaniferous sandstone deposit in the Gallup sandstone, on the Torrivio anticline near Gallup, New Mexico, in the SE¼ sec. 32, T. 15 N., R. 19 W., has been investigated by the New Mexico Bureau of Mines and Mineral Resources. According to Allen (1956, p. 1789) at this locality an olive-green heavy mineral zone which is less than 4 feet thick can be traced N. 25° W. for about 1,000 feet with a width seldom more than 100 feet. The deposit is on a gently sloping bench and is overlain by a coal bed.

Herrera Ranch — An unusual heavy-mineral deposit, on the Herrera ranch in NE¼ SE¼ sec. 31, T. 12 N., R. 2 W., was found several years ago during private airborne reconnaissance but it was recognized as a black-sand deposit only recently. Heavy minerals are present in a buff to gray zone 12 to 14 inches thick in the top of the Gallup sandstone. Only a small portion of the original deposit is preserved; the deposit is overlain by Dilco and exposed in an area 50 feet wide and 200 feet long. Linear zones of intense hematite staining in the top of the Gallup indicate that the deposit originally extended at least 3 miles. The unusual trend of the deposit is N. 17° E.

Dalton Sandstone Member of the Crevasse Canyon Formation

Miguel Creek Dome — The only known deposits in the Dalton sandstone are two small poorly exposed occurrences located on Miguel Creek dome in secs. 4 and 8, T. 15W., R. 6W. The radiometric anomalies caused by these occurrences were discovered late in 1955 during an airborne reconnaissance of the dome. At the deposit in the NE¼ SW¼ sec. 8, an area 200 feet by 150 feet is underlain by as much as 4 feet of rust-brown to brownish-gray sandstone that is exposed on a small bench in a fault block of the Dalton sandstone. The other deposit, in SE¼ NW¼ sec. 4, contains a similar zone of light olive-green sandstone, which is exposed for 200 feet along an arroyo bank in a faulted area.

Point Lookout Sandstone

Southwest Mesa Verde — The black-sand deposits in the Point Lookout sandstone in the southwest Mesa Verde area were located during Atomic Energy Commission airborne reconnaissance during the spring of 1955. For the most part the black sands occur in the Ute Mountain Indian Reservation on mesas directly east of the Shiprock-Cortez highway. The 14 separate deposits that have been found here represent the largest cluster of deposits known in the Basin.

Considerable small-scale intertonguing between the Point Lookout sandstone and the overlying Menefee formation is well exposed in this area. For the most part, the black sands are located in the upper part of the Point Lookout sandstone, and several deposits occur in tongues of the Point Lookout that extend into the basal part of the overlying Menefee formation.

Although the strata are nearly horizontal, the deposits are for the most part exposed only for a short distances along the sides of washes; elsewhere alluvium, dune sands, or talus obscure the deposits. Commonly, they are exposed along drainages where the resistant dark-colored heavy-mineral zone forms ledges above the massive cross-bedded light yellowish-gray Point Lookout sandstone. Generally the deposits are largely covered with alluvium so that only

hard purplish-maroon hematitic sandstone debris marks the outcrop. This "liver-colored" rock is characteristic of the Point Lookout black sands. Although most of the deposits are not well exposed, one in secs. 1, 2, 3, and 12, T. 34 N., R. 17 W., may be traced intermittently for 2-3/4 miles with a maximum width of 250 feet and an exposed thickness of 6 feet. The trend of this deposit is clearly delineated by a series of discontinuous linear ridges, which strike N. 60 W. and are separated by canyons.

A grab sample from a deposit in the NW¼ sec. 3, T. 31 N., R. 16 W., assays 21.5 percent TiO_2, 0.09 percent U_3O_8 equivalent radiometrically, and 0.01 percent U_3O_8 chemically.

Hogback Monocline — Four deposits have been found along the Hogback monocline, a short distance south of the southwest Mesa Verde area. The largest was discovered several years ago, and the others were found during recent Commission airborne reconnaissance. All are poorly exposed, because the hogback trends across the strike of the deposits and thus shows only their narrow dimensions. The deposits are further obscured by talus from higher parts of the ridge. Similar in every respect to the deposits to the north, they occur in the top of the Point Lookout sandstone and two are in tongues of the Point Lookout in the base of the overlying Menefee formation. The largest deposit has been exposed by stripping 525 feet along the north- to northeast trend of the lower ridge of the hogback. The others apparently are about 50 feet wide. The trend of the deposits is obscured by overlying beds.

Standing Rock — A deposit about 4½ miles southeast of Standing Rock Trading Post on the Navajo Indian Reservation was recently discovered by Robert B. O'Sullivan of the U. S. Geological Survey. This deposit is one of the best exposed of any in the Point Lookout sandstone and consists of two rust-brown flat-lying ledges that are elongated northwest and are separated by a small erosional valley. The northwestern portion is about 4,200 feet long with an exposed width of 200 feet; the southeastern portion is about 2,600 feet long and has an exposed width of 500 feet. Separating the ledges is an interval of 4,400 feet. Both ledges have an average thickness of 12 feet and the overall trend is N. 55° W.

Hovey Ranch — Uranium prospectors working in the southeastern part of the San Juan Basin have recently found a deposit on the B. P. Hovey ranch in the SW¼ sec. 34, T. 17 N., R. 4 W. A resistant brownish-gray zone in the top of the Point Lookout is exposed on a cliff near the ranch house. The deposit crops out for a length of 300 feet with a thickness of 2 to 4 feet. A small amount of drilling by the operators has indicated that the deposit trends northwest.

Stinking Lake — Airborne radiometric reconnaissance by the Commission on the Jicarilla Apache Indian Reservation during November and December, 1955, located 3 areas of anomalous radioactivity in the vicinity of Stinking Lake, which ground investigations revealed to be black sands in the top of the Point Lookout sandstone. Two of the anomalies are believed to be the same deposit separated only by thin cover of the overlying Menefee formation. Both deposits are poorly exposed but are easily recognized by the resistant rust-brown to reddish-brown sandstone debris marking the outcrop. The better exposed deposit in the SW¼ sec. 3, T. 28 N., R. 1 E., has an apparent width of 200 feet and a thickness of 5 feet, and it can be traced intermittently for about 2,200 feet in a N. 45° W. direction. The other deposit is just off the Reservation on the Tierra Amarilla Grant in the SE¼ sec. 2, T. 27 N., R. 1 E. (projected). It is also about 5 feet thick, and is exposed along a rim for about 1,000 feet. Slump blocks of the Point Lookout containing the heavy-mineral zone have been observed about one-half mile southeast of the deposit near New Mexico Highway 112.

Herrera Ranch — Another deposit has been reported near the Herrera ranch in the NE¼ sec. 16, T. 11 N., R. 2 W. It is probably in the Point Lookout but has not been examined.

PICTURED CLIFFS SANDSTONE

Star Lake — Airborne radiometric reconnaissance by private interests has located several black-sand deposits in the Pictured Cliffs sandstone near the Star Lake Trading Post on the L. L. Farr Ranch. These deposits are the best exposed of those examined. Two roughly parallel ridges of rust-brown sandstone trend N. 60° W. and stand out in relief against the low rolling topography of the Pictured Cliffs sandstone (fig. 4). Two outlying deposits line up with the trend of the large ridges. By analogy with present-day beach concentrates, the two ridges are thought to represent two separate strand lines and are not remnants of one continuous deposit. The ridges are about 150 feet wide and the longest one is approximately 3,500 feet long. The rust-brown sandstone with visible laminations of dark grains averages about 8 feet in thickness and is separated from the typical massive light yellowish-gray Pictured Cliffs sandstone by a foot of black carbonaceous shale.

Barker Dome — Radioactivity in the Pictured Cliffs

sandstone was located near the Barker dome in sec. 13, T. 31 N., R. 14 W., by a Commission plane early in 1955. Weak radioactivity, associated with a poorly exposed outcrop of rust-brown sandstone, may result from a low concentration of heavy minerals.

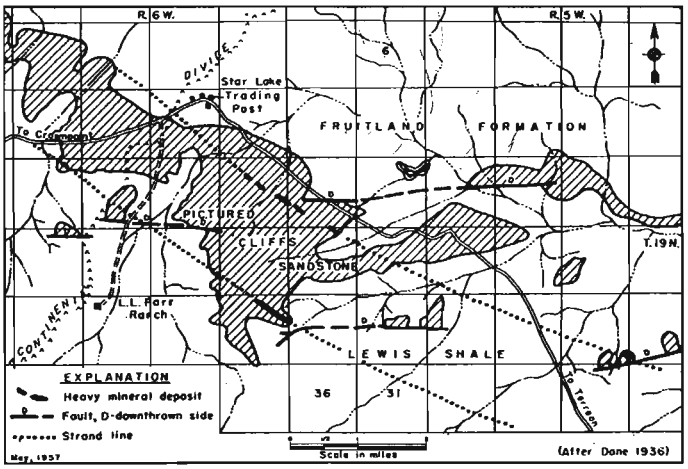

Figure 4. Geologic map of the Star Lake area showing the titaniferous sandstone deposits

Subsurface Occurrences

Of the numerous wells being drilled for natural gas in the San Juan Basin, it is likely that a few would penetrate black-sand deposits in the subsurface. Don W. Mitchell, of Pacific Northwest Pipeline Corp., noted strong radioactivity in the top of the Point Lookout sandstone in three wells drilled by his company near Gobernador (fig. 1). Gamma-ray logs indicate the SJU 30-6, No. 16-26 well, in sec. 26, T. 30 N., R. 6 W., penetrated a radioactive zone between 5862-66 feet; the SJU 29-5, No. 35-34 well, in sec. 34, T. 29 N., R. 5 W., cut it between 5751-57 feet; and the SJU 29-4, No. 7-8 well, in sec. 8, T. 29 N., R. 4 W., encountered radioactivity between 6360-65 feet. Although no cuttings or cores were obtained, it is believed that the radioactivity is caused by a heavy-mineral concentration, since all other radioactivity in the top of the Point Lookout has been traced to such concentrations on the surface. Furthermore these wells fall within a northwest trend between the Stinking Lake deposits and those in the northern part of the southwest Mesa Verde area. Possibly heavy-mineral concentrations were formed near Gobernador along the same shoreline as the outcropping deposits.

Other Possible Deposits

The author believes that many more black-sand deposits may exist in the San Juan Basin and adjacent areas of Upper Cretaceous rocks. Undoubtedly many unreported deposits have been found by prospectors searching for uranium, who did not realize the actual significance of their find. A few deposits are known to exist in the Black Mesa Basin of northern Arizona and single deposits are known both in the Henry Mountains and Kaiparowits Plateau regions of southern Utah.

ECONOMIC POSSIBILITIES

Before complete evaluation of the deposits can be made it will be necessary to determine how the material will respond to current processing techniques. Alteration of the ilmenite and its freedom from intergrowths may make for ease of beneficiation while monazite or other minerals may be recovered as by-products.

The black-sand deposits have not been evaluated with respect to potential tonnage. Rough field estimates of the better exposed deposits indicate about 2-½ million tons of ore are exposed at Sanostee, about 2 million tons are in sight at Standing Rock, and about one-half million tons are in sight at Star Lake.

SUMMARY

(1) Upper Cretaceous rocks of the San Juan Basin contain titaniferous sandstone deposits as significant as any in the Rocky Mountains.

(2) Ilmenite in the deposits is highly altered, and as a result of iron leaching it contains an increased percentage of titanium dioxide. Also, most of the ilmenite is free from intergrowths with magnetite.

(3) Radioactivity, fluorescent zircon, and characteristic sedimentary environment aid in the recognition of new deposits.

MINES AND ORE DEPOSITS NEAR OURAY, COLORADO

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INTRODUCTION

Numerous mines and ore deposits occur within a radius of 2-3 miles of Ouray. Only a few of the more typical deposits will be described here. They are both diverse as to types and variable within individual deposits. Several of the deposits are more or less unique